Development of High Performance Compact Diplexer for Transportable Antenna Terminal

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***Abstract*—This paper presents development of a compact and a robust high performance diplexer implemented using co-axial guide at S-band. It is designed to operate at a power level of around 200 W in the frequency band from 2.02 GHz to 2.3 GHz with an insertion loss better than 1.0 dB. To achieve the stringent isolation requirements between adjacent uplink & downlink frequency bands, higher order filters with a rejection of 100 dB are designed. The diplexer is used in Transportable antenna Terminal for tracking & commanding of satellites & launch vehicles. The measured results conform to the required specifications. In-addition, innovative fabrication aspects are also presented which is extremely critical to successfully achieve such high performance diplexers.**

***Index Terms*— Diplexer, co-axial guide, satellite ground station and transportable terminal.**

I. INTRODUCTION

DIPLEXER is one of the vital components of a satellite ground station which provides required high isolation between the high sensitive receiver and high power transmitter through a common single antenna system. Transportable antenna Terminal (TT) provides the Telemetry, Tracking and Commanding (TT&C) support for launch vehicle & low earth orbiting spacecrafts on a mobile platform. As a result, the TT shall have the capability to be transported by ship / road to the desired place, and shall be able to establish a ground station on ship (or on land) with a minimum integration time. To meet the above requirement, all RF systems on TT shall be compact in size, with-out compromising the performance.

Diplexers have been implemented in varied technology depending on application requirements. Metallic waveguide based diplexers are widely used in very high power applications demanding kilo-watts of power [1], where as micro-strip based diplexers are compact and are mainly used for low power applications operating at few watts of power [2]. For medium power levels like hundreds of watts, co-axial diplexers are considered optimum.

The figure of merit of a ground station is mainly determined by G/T value (G - over all system gain, T - over all system noise temperature). One of the main contributors for higher 'T' is the insertion loss of the interconnecting waveguides/cables, and diplexer. Hence, diplexer for TT shall have low insertion loss with high rejection, be able to operate at reasonably high power (200W) and be compact in size.

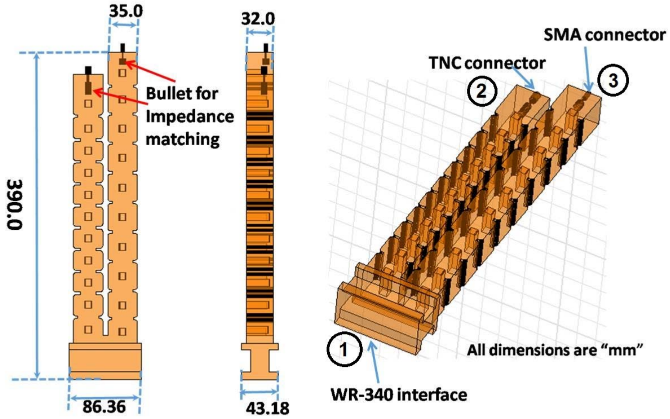

Fig. 1 Diplexer incorporating WR-340 waveguide interface at common port, TNC at uplink and SMA at downlink port.

In this paper, a compact and a robust diplexer to handle power level of hundreds of watts for such ground stations (TT) is proposed. The proposed diplexer (Fig. 1) is implemented using co-axial guide at S-band from 2.025 to 2.12 GHz (uplink/transmit) and 2.2 to 2.3 GHz (downlink/receive). Section II describes the design of proposed diplexer with simulation details. Section III presents fabrication aspects and measured results. Finally, application of present diplexer in the TT is discussed in Section IV.

II. PROPOSED DIPLEXER: DESIGN DETAILS

A. *Specifications*

The TT ground station is designed with single antenna feed for uplink and downlink, and the diplexer performs the function of band limiting at respective frequency bands as well as provides sufficient isolation between them. The diplexer is designed for following specifications: uplink frequency band from 2.02 GHz to 2.12 GHz, downlink frequency band from 2.20 GHz to 2.30 GHz, return loss ≥ 15.0 dB, mid-band insertion loss ≤ 1.0 dB, rejection at other frequency band ≥ 100.0 dB, power handling ≥ 200 W, interface: TNC Jack at uplink port, SMA Jack at downlink port and WR-340 waveguide at common antenna port.

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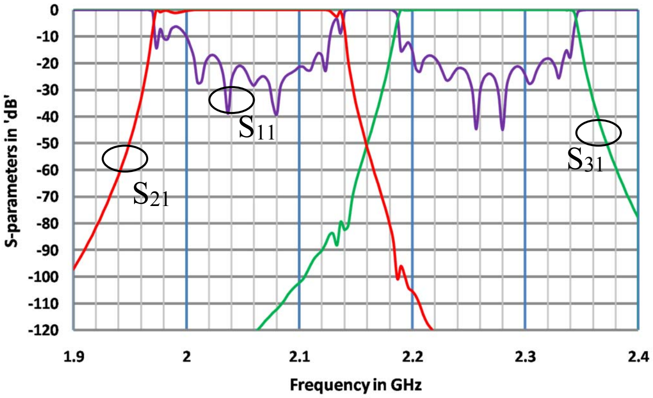

Fig. 2 Simulated response of the proposed diplexer in WASP-NET.

B. Diplexer in Co-axial Guide

Fig. 1 depicts the 3D simulation model of the diplexer. For clarity, multiple views are shown in the figure. The diplexer is composed of two compact combline band pass filters connected to a common port which is standard waveguide WR340. Combline resonator is a hybrid structure, where a co-axial transmission line is formed by a partial height post in series with a gap capacitor placed in a rectangular (or circular) cavity. Due to the below cut-off waveguide housing, combline (or evanescent mode waveguide) filters are compact in size and can provide moderate bandwidth with excellent out-of-band performance and sharp selectivity [3] – [6]. Furthermore, inductive iris is used for inter-resonator coupling to reduce the filter length [7]. Rectangular cavity of 32 × 35 mm^2 dimensions is used in the diplexer.

TNC connector is used for transmitter interface to handle 200 W [8], and SMA connector is used for receiver interface. These interfaces are included in the design itself and optimized to minimize the size and insertion loss of the diplexer. WASP-NET software, based on mode matching technique, is used for the design & optimization [9]. Fig. 2 depicts the simulated response of the diplexer, where the reflection co-efficient at the common port, the transmission co-efficient between the common port and uplink & downlink ports are shown. It can be observed from the figure that the rejection is better than 100 dB at the adjacent bands.

Power handling of combline filter is limited by the gap capacitance formed between the resonator open end and ground plane where the electric field has its maximum intensity [10]. This gap is typically a small fraction of the wavelength, making it susceptible to corona or arc discharge. Due to this reason, combline filters are usually not used for high power applications. However, by increasing the critical gap at the design stage and curving the resonator posts with suitable radius, power handling capability can be increased while still maintaining high performance [10]. Electro-magnetic field analysis in HFSS indicates that the diplexer can handle peak power of around 1.2 kW, considering air breakdown as 2.2×10^6 V/m [11], [12].

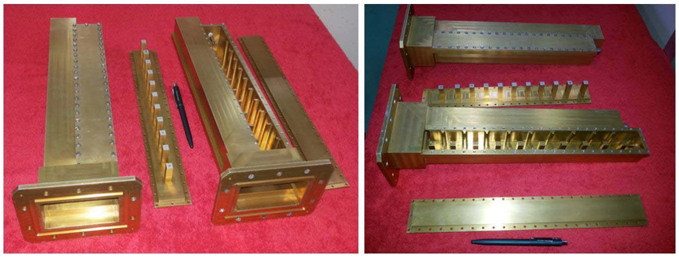

Fig. 3 Photograph of the proposed diplexer implemented in co-axial guide: assembled & disassembled (common port - WR-340, transmitter port – TNC connector, receiver port - SMA connector)

III. PROPOSED DIPLEXER: MEASURED RESULTS

Fig. 3 shows the photograph of the fabricated diplexer. Chromated aluminum is used for realizing the diplexer. Inner pins of TNC & SMA connectors are soldered to suitable metal bullets made from beryllium copper. Since both filters have common housing, one of the realization challenge is to minimize the cross coupling between the filters which might result from leakage of currents especially from high power transmit filter towards receive filter.

To minimize this cross coupling between the filter sections using better mechanical isolation, an innovative 'S' type of construction is adopted in the diplexer. Where, the entire diplexer is fabricated using 3 sections: the main housing, a plain cover plate and a cover plate with posts as depicted in Fig. 3. This innovative fabrication is extremely critical especially to achieve high rejection levels of better than 100 dB at the close by adjacent bands.

The diplexer is characterized using Agilent Network Analyzer. The measured S-parameters of downlink in-band and out of band rejection is shown in Fig. 4. Similarly, measured S-parameter of uplink in-band and out of band rejection is shown in Fig. 5. Table-1 summarizes the measured results against specifications. It is evident from the contents of Table-1, that measured results of the diplexer are in good matching with specifications. It may be noted that measured results include the effect of TNC to SMA and WR-340 waveguide to SMA adaptors as well.

IV. DIPLEXER APPLICATION IN TRANSPORTABLE ANTENNA TERMINAL

For supporting Deep Space Missions, a large number of ground stations are required to provide Telemetry Tracking and Command (TTC) support during the launch and initial phase. Based on the launch vehicle trajectory and visibility requirement, many a time, the TTC stations are to be located in mid sea, wherein, conventional Ground Station Antenna will not be suitable. In order to cater to these specific requirements, a 4.6 meter Ship Borne Transportable (SBT) Antenna Terminal (as shown in Fig. 6) was developed, which meets the launch vehicle TTC requirements [13]. The SBT Antenna system consists of 3-axis Antenna Mount, a Motion Simulator, Reflector & Feed, Servo Control Systems and RF Electronics. A high efficiency, 4.6 meter reflector antenna in Axially Displaced Ellipsoid (ADE) configuration is designed for use in SBT to extend the TT&C coverage area.

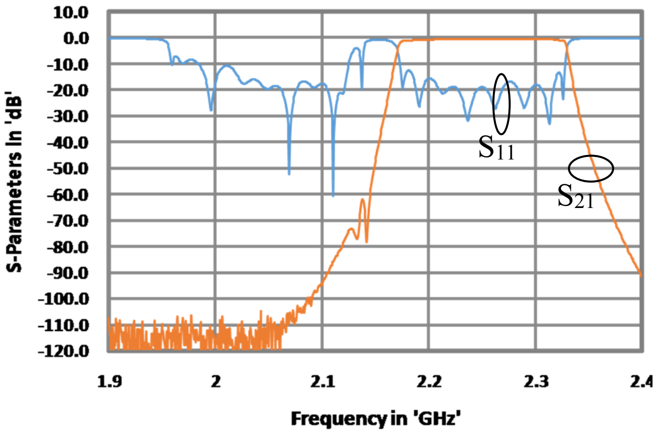

Fig. 4 Measured S-parameters of down link path

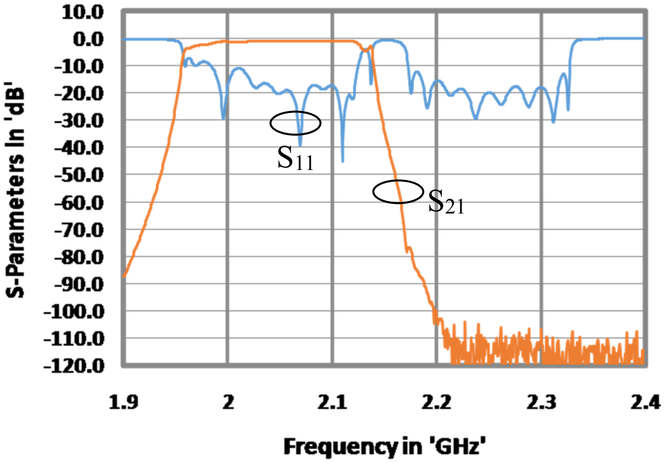

Fig. 5 Measured S-parameters of up-link path.

TABLE I: SUMMARY OF DIPLEXER: MEASURED RESULTS

Parameter	Specifications	Measured
Frequency (GHz)	Uplink: 2.02-2.12 Downlink: 2.2 – 2.3	Uplink: 2.02-2.12 Downlink: 2.2 – 2.3
Insertion loss (dB)	Uplink: < 1.00 Downlink: < 0.80	0.85 0.46
Return loss (dB) (both bands)	15.0 (min)	18.0
Rejection at 2.20 GHz Rejection at 2.12 GHz	100.0 dB (min) 70.0 dB (min)	105.0dB 79.0dB
Power handling requirement	200 W (uplink only)	*200W
Interface Downlink port Uplink port Common port	SMA Jack TNC Jack WR-340	SMA Jack TNC Jack WR-340

*The diplexer is integrated to the TT ground station and is working with 200W of power at uplink successfully.

The complete feed consists of a centre horn for normal TT&C application (Uplink and Downlink) and four horns, surrounding the central horn, which as an array used for tracking the satellite. Since the centre horn is used for both the TT&C uplink and downlink operations, it is designed for a bandwidth of 300 MHz at 2.15 GHZ and followed by a diplexer in the system, as shown in inset of Fig. 6 to provide high isolation between the high power transmitter and sensitive receiver.

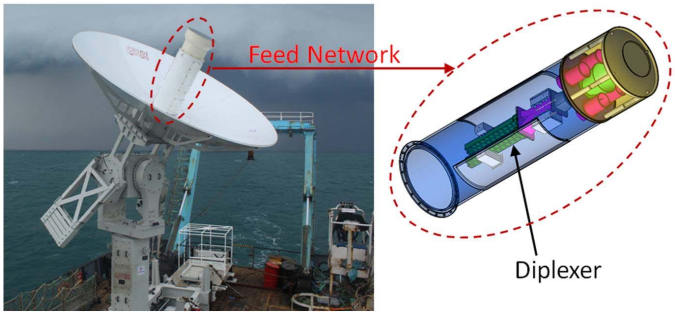

Fig. 6. ISRO Ship borne Transportable (SBT) Antenna Terminal [13].

V. CONCLUSION

A compact, low loss, medium power and a robust diplexer realized using co-axial guide is presented in this paper. The diplexer is used in transportable antenna terminal ground station for tracking and commanding of low earth orbiting satellites/launch vehicles. The diplexer can handle medium power level of around 200W with insertion loss better than 1.0 dB in uplink band better than 0.6 dB in downlink band and 100.0dB rejection at other band. It is evident from measured results that the realized diplexer meets all the specifications. In-addition, innovative fabrication aspects are also presented which is extremely critical to successfully achieve such high rejections.

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